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METHOD AND PLANT FOR THE HEAT TREATMENT
OF SULFIDIC ORES USING ANNULAR FLUIDIZED BED

Technical Field

- 5 The present invention relates to a method for the heat treatment of in particular sulfidic ores, in which fine-grained solids are treated at a temperature of 450 to approximately 1500°C in a first fluidized bed reactor, and to a corresponding plant.
- 10 Such a method and a plant for the treatment of sulfidic ores containing gold are known for example from DE 196 09 286 A1. In that case, the ore is fluidized in a circulating fluidized bed of a roasting reactor by a gas containing oxygen, with metal sulfides being converted into metal oxides and an exhaust gas containing SO₂ being obtained.
- 15 It is further known to roast sulfidic ores, such as for example zinc blende, in a stationary fluidized bed furnace at temperatures between 500 and 1100°C with air being supplied. In this roasting of zinc blende in a stationary fluidized bed furnace, up to 1000 metric tons of blende per day can be processed.
- 20 The energy utilization of the heat treatment achieved when using a stationary fluidized bed is felt to be in need of improvement. One reason for this is that the mass and heat transfer is rather moderate on account of the comparatively low degree of fluidization. Furthermore, in the case of stationary fluidized beds, fine
- 25 particles are discharged too quickly from the reactor, so that the retention time in the plant is not adequate for a complete reaction. This problem arises especially in the case of circulating fluidized beds due to the higher degree of fluidization, although better mass and heat transfer conditions prevail. Since the sulfidic ores used for the heat treatment, such as for example gold ore, zinc blende
- 30 or concentrate, become increasingly fine, for example with a grain size fraction

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below 45 μm of 75%, an adequate roasting result can only be achieved with difficulty with the known methods and plants.

Moreover, in the case of the known methods and plants, the temperature in the reactor can scarcely be regulated, further impairing the roasting result.

Description of the Invention

Therefore, it is the object of the present invention to provide a method for the heat treatment of sulfidic ores which can be carried out more efficiently and is distinguished in particular by better roasting results along with good conditions for heat and mass transfer.

In accordance with the invention, this object is achieved by a method as mentioned above in which a first gas or gas mixture is introduced from below through a preferably centrally arranged gas supply tube (central tube) into a mixing chamber region of the reactor, the central tube being at least partly surrounded by a stationary annular fluidized bed which is fluidized by supplying fluidizing gas, and in which the gas velocities of the first gas or gas mixture as well as of the fluidizing gas for the annular fluidized bed are adjusted such that the particle Froude numbers in the central tube are between 1 and 100, in the annular fluidized bed between 0.02 and 2 and in the mixing chamber between 0.3 and 30.

In the method of the invention, the advantages of a stationary fluidized bed, such as a longer solids retention time, and the advantages of a circulating fluidized bed, such as a good mass and heat transfer, can surprisingly be combined with each other during the heat treatment, such as for example the roasting of sulfidic ores, while the disadvantages of both systems are avoided. When passing through the upper region of the central tube, the first gas or gas mixture en-

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trains solids from the annular stationary fluidized bed, which is referred to as the annular fluidized bed, into the mixing chamber, so that, due to the high speed differences between the solids and the first gas, an intensively mixed suspension is formed and an optimum heat and mass transfer between the two phases is achieved. By correspondingly adjusting the bed height in the annular fluidized bed as well as the gas velocities of the first gas or gas mixture and of the fluidizing gas, the solids load of the suspension above the orifice region of the central tube can be varied within wide ranges, so that the pressure loss of the first gas between the orifice region of the central tube and the upper outlet of the mixing chamber can be between 1 mbar and 100 mbar. In the case of high solids loading of the suspension in the mixing chamber, a large part of the solids will separate out from the suspension and fall back into the annular fluidized bed. In this way, the temperature in the annular fluidized bed can also be regulated by the amount of heated particles separating out. This recirculation is called internal solids recirculation, the stream of solids circulating in this internal circulation normally being significantly larger than the amount of solids supplied to the reactor from outside. The (smaller) amount of not precipitated solids is discharged from the mixing chamber together with the first gas or gas mixture. The retention time of the solids in the reactor can be varied within a wide range by the selection of the height and cross-sectional area of the annular fluidized bed and be adapted to the desired heat treatment. The amount of solids entrained from the reactor with the gas stream can be completely or at least partly recirculated to the reactor, with the recirculation expediently being fed into the stationary fluidized bed. The stream of solids thus recirculated to the annular fluidized bed normally lies in the same order of magnitude as the stream of solids supplied to the reactor from outside. With the method of the invention, on the one hand a high solids loading and at the same time a particularly good mass and heat transfer can consequently be achieved. Apart from the excellent utilization of energy, another advantage of the method in accordance with the invention consists in the possibility of quickly, easily and reliably adjusting the transfer of en-

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ergy of the method and the mass transfer to the requirements by changing the flow velocities of the first gas or gas mixture and of the fluidizing gas.

5 The heat transfer can be further intensified if the reactor is provided downstream with a second reactor, into which a gas mixture laden with solids is introduced from the first reactor. This preferably takes place from below through a, for example central, gas supply tube into a mixing chamber, the gas supply tube being surrounded at least partly by a stationary annular fluidized bed which is fluidized by supplying fluidizing gas. In principle, a single reactor is adequate for performing the method according to the invention. However, the combination of a reactor with a second reactor of a similar type of construction to form a reactor stage allows the overall retention time of the solids in the plant to be increased distinctly.

15 To ensure a particularly effective heat transfer in the mixing chamber and a sufficient retention time in the reactors, the gas velocities of the first gas mixture and of the fluidizing gas are preferably adjusted for the fluidized bed such that the dimensionless particle Froude numbers (Fr_p) are 1.15 to 20, in particular between 3.95 and 11.6, in the central tube, 0.11 to 1.15, in particular between 0.11 and 0.52, in the annular fluidized bed, and/or 0.37 to 3.7, in particular between 0.53 and 1.32, in the mixing chamber. The particle Froude numbers are each defined by the following equation:

$$Fr_p = \frac{u}{\sqrt{\frac{(\rho_s - \rho_f)}{\rho_f} * d_p * g}}$$

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with

u = effective velocity of the gas flow in m/s

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ρ_f = effective density of the fluidizing gas in kg/m^3

ρ_s = density of a solid particle in kg/m^3

d_p = mean diameter in m of the particles of the reactor inventory (or the particles forming) during operation of the reactor

5 g = gravitational constant in m/s^2 .

When using this equation it should be considered that d_p does not indicate the mean diameter (d_{50}) of the material used, but the mean diameter of the reactor inventory formed during the operation of the reactor, which can differ significantly in both directions from the mean diameter of the material used (primary particles). It is also possible for particles (secondary particles) with a mean diameter of 20 to 30 μm to be formed for instance during the heat treatment from very fine-grained material with a mean diameter of, for example, 3 to 10 μm . On the other hand, some materials, for example ores, are decrepitated during the heat treatment.

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In a development of the idea of the invention, it is proposed to adjust the bed height of solids in the reactor or the reactor stage such that the annular fluidized bed extends beyond the upper orifice end of the central tube by a few centimetres, and thus solids are constantly introduced into the first gas or gas mixture and entrained by the gas stream to the mixing chamber located above the orifice region of the central tube. In this way, there is achieved a particularly high solids loading of the suspension above the orifice region of the central tube.

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By means of the method in accordance with the invention, all kinds of sulfidic ores, in particular also those which contain gold, zinc, silver, nickel, copper and/or iron, can be effectively heat-treated. In particular, the method is suitable for the roasting of gold ore or zinc blende. The intensive mass and heat transfer and the adjustable retention time in the reactors allows a particularly high degree of conversion of the roasted material to be achieved.

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The generation of the amount of heat necessary for the operation of the reactor can be effected in any way known to the expert for this purpose. According to a preferred embodiment of the present invention, it is provided that, for the roasting, the reactors are supplied with oxygen-containing gas, for example with an oxygen content of approximately 20 vol-%, which is introduced into the annular fluidized beds of the reactors. The gas may be air, air enriched with oxygen or some other oxygen-containing gas. The oxygen-containing gas is preferably introduced into the reactor or the reactors with a temperature of approximately 25 to 50°C. The process of roasting sulfidic ores with excess of oxygen to form metal oxides is exothermal, so that usually no further heat has to be supplied to the reactor or the reactor stage.

The energy utilization can be further improved in the case of the method in accordance with the invention by heat being supplied to or extracted from the first and/or second reactor in the annular fluidized bed and/or in the mixing chamber. Thus, in the case of an exothermal reaction, for example, the generated heat can be used in the reactor for steam generation for example.

A cooling device is preferably provided downstream of the second reactor, in order to cool the solids-laden gas mixture emerging from the reactor to a temperature suitable for the further treatment of below 400°C, in particular to approximately 380°C. This cooling device may also be used for example for generating water vapour, whereby the energy utilization of the overall method is further improved.

A separator, for example a cyclone or the like, may be provided downstream of the reactor stage. The solids separated from exhaust gases can be returned from the separator into the reactor stage, for example into the annular fluidized bed, from one or more reactors, or be passed on to a further cooling device.

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The retention time of the solids in the reactor stage can be varied in this way. In addition, the bed height of the solids in one or more reactors can be deliberately adapted to the requirements. The bed height in the annular fluidized bed in this case also influences the temperature established in the annular fluidized bed, since more particles are entrained into the mixing chamber and separated out from it in a heated state when there is a higher bed height. In this way, the temperature in the reactor can be deliberately regulated by the amount of solids recirculated from the separator.

Preferably provided downstream of the separator is a gas cleaning stage with a hot-gas electrostatic precipitator and/or a wet-gas treatment, in which at least part of the exhaust gases separated from the solids in the separator is further cleaned. The cleaned exhaust gases can then be returned, for example as preheated fluidizing gas, into the annular fluidized bed of the first and/or second reactor. Part of the exhaust gas separated from the solids in the separator may also be supplied to a plant for producing sulfuric acid. The SO₂-containing exhaust gases of the reactor stage can in this way be used for producing a by-product.

Coarse-grained solids and/or roasting residue are drawn off from the annular fluidized bed of the first and/or second reactor and passed on to a further cooling device, for example a fluidized bed cooler. The discharge of the solids or of the roasting residue may in this case take place discontinuously, whereby the amount of solids in the reactor stage can at the same time be regulated.

A plant in accordance with the invention, which is in particular suited for performing the method described above, has a reactor constituting a fluidized bed reactor for the heat treatment of sulfidic ores, the reactor having a gas supply system which is formed such that gas flowing through the gas supply system entrains solids from a stationary annular fluidized bed, which at least partly sur-

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rounds the gas supply system, into the mixing chamber. Preferably, this gas supply system extends into the mixing chamber. It is, however, also possible to let the gas supply system end below the surface of the annular fluidized bed. The gas is then introduced into the annular fluidized bed for example via lateral
5 apertures, entraining solids from the annular fluidized bed into the mixing chamber due to its flow velocity.

In accordance with a preferred aspect of the invention, the gas supply system has a central tube extending upwards substantially vertically from the lower re-
10 gion of the reactor, which is at least partly surrounded in an annular manner by a chamber in which the stationary annular fluidized bed is formed. The annular fluidized bed does not have to be annular, but rather other forms of the annular fluidized bed are also possible, in dependence on the geometry of the central tube and the reactor, as long as the central tube is at least partly surrounded by
15 the annular fluidized bed.

Of course, two or more central tubes with different or identical dimensions or shapes may also be provided in the reactor. Preferably, however, at least one of the central tubes is arranged approximately centrally with reference to the
20 cross-sectional area of the reactor.

In accordance with a further embodiment of the present invention, the central tube has apertures on its shell surface, for example in the form of slots, so that during the operation of the reactor solids constantly get into the central tube
25 through the apertures and are entrained by the first gas or gas mixture from the central tube into the mixing chamber.

In order to increase the throughput of the plant or the solids retention time, instead of a single reactor there may also be a number of reactors, in particular
30 two, connected to form a reactor stage. The reactors preferably have in each

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case an annular chamber for a stationary annular fluidized bed and a mixing chamber for the formation of a circulating fluidized bed, the central tube of a downstream reactor being connected to the exhaust-gas outlet of the reactor provided upstream of it.

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In accordance with a preferred embodiment, a separator, in particular a cyclone, is provided downstream of the reactor, or the reactor stage, for the separation of solids. The separator may have a solids conduit leading to the annular fluidized bed of the first reactor and/or a solids conduit leading to the annular fluidized bed of a second reactor possibly provided downstream.

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If a cooling device is provided downstream of the reactor stage, the solids-laden gas mixture discharged from the reactor stage can be cooled before further treatment to the temperature required for this. A waste-heat boiler provided with banks of cooling tubes may be used for example as the cooling device, it being possible for the banks of cooling tubes to serve at the same time for steam generation.

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Furthermore, the temperature required for the heat treatment may be exactly adjusted in the first and/or second reactor by means of temperature-control elements. For this purpose, the reactor may be provided as a natural circulation boiler with cooling elements and membrane walls.

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To provide for a reliable fluidization of the solids and the formation of a stationary fluidized bed, provided in the annular chamber of the first reactor and/or the further reactors is a gas distributor which divides the chamber into an upper fluidized bed region and a lower gas distributor chamber. The gas distributor chamber is connected to a supply conduit for fluidizing gas. Instead of the gas distributor chamber, a gas distributor composed of tubes may also be used.

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Preferably, the separator of the reactor or of the reactor stage is connected to a supply conduit leading into the annular chamber of a reactor, so that the exhaust gas, possibly further cleaned beforehand, can be used as a pre-heated fluidizing gas.

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As an alternative or in addition to this, a dedusting device and/or a plant for producing sulfuric acid may be provided downstream of the separator of the reactor or of the reactor stage.

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In the annular fluidized bed and/or the mixing chamber of the reactor, means for deflecting the solids and/or fluid flows may be provided in accordance with the invention. It is for instance possible to position an annular weir, whose diameter lies between that of the central tube and that of the reactor wall, in the annular fluidized bed such that the upper edge of the weir protrudes beyond the solids level obtained during operation, whereas the lower edge of the weir is arranged at a distance from the gas distributor or the like. Thus, solids raining out of the mixing chamber in the vicinity of the reactor wall must first pass by the weir at the lower edge thereof, before they can be entrained by the gas flow of the central tube back into the mixing chamber. In this way, an exchange of solids is enforced in the annular fluidized bed, so that a more uniform retention time of the solids in the annular fluidized bed is obtained.

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Developments, advantages and application possibilities of the invention also emerge from the following description of an exemplary embodiment and the drawing. All features described and/or illustrated in the drawing form the subject-matter of the invention per se or in any combination, independently of their inclusion in the claims or their back-reference.

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Brief Description of the Drawings

The single figure shows a process diagram of a method and a plant in accordance with an exemplary embodiment of the present invention.

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Detailed Description of a Preferred Embodiment

10 In the method shown in the figure, which is in particular suited for the heat treatment of sulfidic ores, solids are introduced into a first reactor 1 via a supply conduit 2. The reactor 1, which is cylindrical for example, has a central tube 3, which is arranged approximately coaxially with the longitudinal axis of the reactor and extends substantially vertically upwards from the bottom of the reactor 1.

15 Provided in the region of the bottom of the reactor 1 is an annular gas distributor chamber 4, which is closed off at the top by a gas distributor 5 having apertures. A supply conduit 6 opens out into the gas distributor chamber 4. Arranged in the vertically upper region of the reactor 1, which forms a mixing chamber 7, is a discharge conduit 8, which opens out into a second reactor 9.

20 The second reactor 9 is largely similar in construction to the first reactor 1. Extending from the bottom of the reactor 9 substantially vertically upwards is a central tube 10, which is connected to the discharge conduit 8 of the first reactor 1 and is arranged approximately coaxially with the longitudinal axis of the reactor 9.

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Provided in the region of the bottom of the reactor 9 is an annular gas distributor chamber 11, which is closed off at the top by a gas distributor 12 having apertures. A supply conduit 13 opens out into the gas distributor chamber 11. A further supply conduit 14 is provided for introducing solids into the reactor 9 during the starting-up of the plant.

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Temperature-control elements 15 and 16, which are for example flowed through by water, are arranged above the gas distributors 5 and 12, respectively, of the two reactors. In addition, the walls of the reactors 1 and 9 are formed as membrane walls 17 and 18, respectively, which are connected to further temperature-control elements which are not represented in the figure and are for example flowed through by water. In this way, the reactors form a so-called natural circulation boiler.

Arranged in the vertically upper region of the second reactor 9, which forms a mixing chamber 19, is a waste-heat boiler 21 provided with banks of cooling tubes 20. Via a conduit 22, the waste-heat boiler 21 is in connection with a separator, which is formed as a cyclone 23. A solids conduit 24 returns the solids from a floating tank 25, provided downstream of the cyclone 23, into the reactors 1 or 9 or supplies the solids to a further cooling device 26. Arranged above the gas distributors 5 and 12 of the two reactors are discharge conduits 27 and 28 for coarse-grained solids and/or roasting residue, which are connected to the further cooling device 26. The cooling device 26 is formed as a fluidized bed cooler, in which the stream of product is subjected to fluidizing air and cooled by a cooling element 29.

Via a conduit 30, the exhaust gas separated from the solids from the cyclone 23 is supplied to a gas cleaning stage, which has a hot-gas electrostatic precipitator 31 and wet-gas cleaning 32. The dedusted exhaust gas can either be passed on to a plant 33 for the production of sulfuric acid and/or via conduit 34 as fluidizing gas into the reactors 1 and 9 via conduits 6 and 13, respectively. Further gas, which may also be a different gas, may in this case be supplied to the fluidizing gas after cleaning.

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During operation of the plant, solids are introduced into the reactor 1 via the supply conduit 2, so that a layer annularly surrounding the central tube 3, which is referred to as an annular fluidized bed 35, forms on the gas distributor 5. Fluidizing gas introduced into the gas distributor chamber 4 through the supply conduit 6 flows through the gas distributor 5 and fluidizes the annular fluidized bed 35, so that a stationary fluidized bed is formed. The velocity of the gases supplied to the reactor 1 is adjusted such that the particle Froude number in the annular fluidized bed 35 is approximately 0.11 to 0.52.

By supplying further solids into the annular fluidized bed 35, the level of the solids in the reactor 1 increases to the extent that solids enter the orifice of the central tube 3. At the same time, a gas or gas mixture is also introduced into the reactor 1 through the central tube 3. The velocity of the gas supplied to the reactor 1 is preferably adjusted such that the particle Froude number in the central tube 3 is approximately 3.95 to 11.6 and in the mixing chamber 7 approximately 0.53 to 1.32. Due to these high gas velocities, the gas flowing through the central tube 3 entrains solids from the stationary annular fluidized bed 35 into the mixing chamber 7 when passing through the upper orifice region.

Due to the banking of the level of the annular fluidized bed 35 as compared to the upper edge of the central tube 3, solids flow over this edge into the central tube 3, whereby an intensively mixed suspension is formed. The upper edge of the central tube 3 may be straight, corrugated or indented or have lateral apertures. As a result of the reduction of the flow velocity by the expansion of the gas jet and/or by impingement on one of the reactor walls, the entrained solids in the mixing chamber 7 quickly lose speed and partly fall back again into the annular fluidized bed 35. The amount of not precipitated solids is discharged from the reactor 1 together with the gas stream via the conduit 8 and passed into the reactor 9. Between the reactor regions of the stationary annular fluid-

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ized bed 35 and the mixing chamber 7 there is thereby obtained a solids circulation which ensures a good heat transfer.

Before further processing, the solids discharged via the conduit 8 are treated in
5 the second reactor 9 in the way explained above with reference to reactor 1, so
that a stationary fluidized bed 36 is likewise formed above the gas distributor 12
in the reactor 9 by solids separating out from the mixing chamber 19. Moreover,
the dust separated in the hot-gas electrostatic precipitator 31 is returned via a
recirculating conduit into the stationary annular fluidized bed 36 of the second
10 reactor 9. The particle Froude numbers in the second reactor 9 correspond approximately to those of the first reactor 1.

The bed height of the solids in the reactors 1 and 9 is regulated not only by the
supply of solids via conduit 2 but also firstly by means of the amount of solids
15 returned from the cyclone 23 into the reactors and moreover by means of the
amount of solids extracted from the reactors via conduits 27 or 28.

The solids removed from the cyclone 23 and/or directly from the reactors 1 and
9 are cooled in the fluidized bed cooler 26 to a temperature suitable for the further
20 processing. After cleaning in the hot-gas electrostatic precipitator 31 and
the wet-gas cleaning 32, the exhaust gas separated from the solids in the cyclone 23
can be partly supplied to the reactors as pre-heated fluidizing gas or to
the sulfuric acid plant 33.

25 The invention will be described below with reference to two examples demonstrating the inventive idea, but not restricting the same.

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Example 1 (roasting of gold ore)

In a plant corresponding to the figure, 1200 kg/h of ground, dried and classified gold ore with a gold content of approximately 5 ppm, i.e. 5 g/t, and a maximum grain fraction of 50 μm , containing

1.05 wt-% organic carbon

19.3 wt-% CaCO_3

12.44 wt-% Al_2O_3

2.75 wt-% FeS_2

64.46 wt-% inert substances (for example SiO_2),

were supplied in continuous operation to the reactor 1, the upper part of which had a diameter of 800 mm. Furthermore, 2500 Nm^3/h of air with a temperature of 520°C were introduced into the reactor 1 via the central tube 3 and via conduit 6 as fluidizing gas. The particle Froude number was in this case between 3.95 and 6.25 in the central tube 3, between 0.84 and 1.32 in the mixing chamber 7 and between 0.32 and 0.52 in the annular fluidized bed 35.

The retention time of the gold ore in the reactor 1 was between 5 and 10 minutes, with a temperature of between 600 and 780°C being established in the reactor. 0.5 to 6.0 vol-% of residual oxygen were measured in the exhaust gas. The content of organic carbon in the product after the heat treatment was below 0.1%.

Example 2 (roasting of zinc blende)

In a plant corresponding to the figure, 42 t/h of zinc blende with a temperature of approximately 25°C were supplied to the reactor 1 from a charging bunker with a capacity of about 200 m^3 via conduit 2 and a dosing device into the annular

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fluidized bed 35. At the same time, approximately 16,600 Nm³/h of air with a temperature of 47°C and a pressure of approximately 1.2 bar, containing

77.1 vol-% N

5 20.4 vol-% O₂

2.5 vol-% H₂O,

were introduced via conduit 6 to the annular fluidized bed. Approximately 60,200 Nm³/h of air and additionally 3000 Nm³/h of exhaust cooler air from the fluidized
10 bed cooler 26 with a temperature of 150°C were passed through the central tube 3 to the reactor 1, so that the total amount of air passed to the central tube 3 was approximately 63,200 Nm³/h. The air had a temperature of 35°C and a pressure of 1.07 bar and contained

15 77.1 vol-% N

20.4 vol-% O₂

2.5 vol-% H₂O.

The particle Froude number was in this case between 4.4 and 11.6 in the central
20 tube 3, between 0.53 and 1.15 in the mixing chamber 7 and between 0.11 and 0.3 in the annular fluidized bed 35. The reaction of the sulfidic zinc blende with the free oxygen of the fluidizing air to form metal oxide caused a temperature of 930°C to be established in the reactor 1. At the same time, approximately 15.4 MW of heat were extracted from the reactor 1 via the cooling element 15 and
25 the membrane wall 17 and used to generate saturated steam from cooling water. The temperature in the region of the conduit 8 at the outlet of the reactor 1 was thereby lowered to 800°C. To avoid an enrichment of coarse material in the reactor 1, approximately 0.16 t/h of product with a temperature of 901°C were
30 extracted from the annular fluidized bed 35 in discontinuous operation via conduit 27 as coarse-grained run-off and passed to the fluidized bed cooler 26.

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A solids-laden gas mixture with a pressure of 1.049 bar comprising 110.9 t/h of solids and approximately 79,600 Nm³/h of exhaust gas, containing

5 12.1 vol-% SO₂
 77.2 vol-% N
 2.5 vol-% O₂
 8.2 vol-% H₂O,

10 were passed to the central tube 10 of the second reactor 9 via conduit 8. Furthermore, approximately 17,350 Nm³/h of air with a temperature of 43°C at a pressure of approximately 1.18 bar, containing

 77.1 vol-% N
15 20.4 vol-% O₂
 2.5 vol-% H₂O,

 were supplied to the reactor 9 via conduit 13 for fluidization. During start-up operation, 5 t/h of solids with a temperature of 25°C were at the same time
20 charged to the reactor 9 via conduit 14. The solids-laden gas mixture was cooled to 480°C in the mixing chamber 19 of the reactor 9, with a total of approximately 23.6 MW of heat being removed from the reactor 9 by the cooling element 16, the membrane wall 18 and the waste-heat boiler 21 and used to generate saturated steam from cooling water. The cooling element 16 was in
25 this case used as a steam superheater with a superheating temperature of 400°C.

 Approximately 96,200 Nm³/h of solids-laden gas mixture with a temperature of 380°C and a pressure of 1.018 bar, which was laden with 213.5 t/h of solids and
30 had the following composition:

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9.4 vol-% SO₂

77.8 vol-% N

5.5 vol-% O₂5 7.3 vol-% H₂O

were removed from the reactor 9 via conduit 22.

10 In the cyclone 23, the exhaust gas was separated from the solids to the extent that approximately 96,200 Nm³/h of air with a dust content of 50 g/Nm³ (4.81 t/h of solids) were passed on to the hot-gas electrostatic precipitator 31 via conduit 30. There, the exhaust gas was dedusted to a dust content of 50 mg/Nm³ and passed on to the wet-gas cleaning 32 and the downstream sulfuric acid plant 33.

15 From the cyclone 23, approximately 208 t/h of solids with a temperature of 380°C were passed firstly to the floating tank 25, serving as a buffer vessel, and divided in such a way that 76.2 t/h were passed into the annular fluidized bed 35 of the first reactor 1, approximately 100.9 t/h into the annular fluidized bed 36 of the second reactor 9 and 31 t/h into the fluidized bed cooler 26.

20 In this way it was possible for the bed height of the annular fluidized beds 35 and 36, respectively forming in the two reactors 1 and 9, to be adjusted to approximately 1 m. The solids were then cooled in the fluidized bed cooler 26 by the cooling element 29 to a temperature of below 150°C, with an amount of heat
25 of approximately 1.7 MW being removed. As a result, a total of approximately 40.8 MW were removed from the plant and converted into 55.2 t/h of superheated steam with a pressure of 40 bar and a temperature of 400°C.

30 The product discharged from the fluidized bed cooler 26 was mixed with approximately 4.8 t/h of solids with a temperature of approximately 380°C, which

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were separated from the exhaust gas of the cyclone 30 by the hot-gas electrostatic precipitator 31. The stream of product discharged altogether from the plant was consequently approximately 36.54 t/h at a temperature of approximately 182°C.

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In this way it was possible for even zinc blende or a zinc blende concentrate with a grain size fraction below 45 μm of 75% to be roasted in the plant in such a way that the end product contained 0.3 wt-% of sulfide sulfur and 1.8 wt-% of sulfate sulfur.

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List of Reference Numerals:

1	(first) reactor	19	mixing chamber
2	(solids) supply conduit	20	bank of cooling tubes
3	central tube (gas supply tube)	21	waste-heat boiler
4	gas distributor chamber	22	conduit
5	gas distributor	23	cyclone
6	(gas) supply conduit	24	conduit
7	mixing chamber	25	floating tank
8	conduit	26	fluidized bed cooler
9	(second) reactor	27	conduit
10	central tube (gas supply tube)	28	conduit
11	gas distributor chamber	29	cooling element
12	gas distributor	30	conduit
13	(gas) supply conduit	31	hot-gas electrostatic precipitator
14	(solids) supply conduit	32	wet-gas cleaner
15	temperature-control element	33	plant for producing sulfuric acid
16	temperature-control element	34	conduit
17	membrane wall	35	annular fluidized bed
18	membrane wall	36	annular fluidized bed